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A TREATISE ON ECHINOCOCCUS DISEASE

By E. P. HELLER, M.D.

Kansas City

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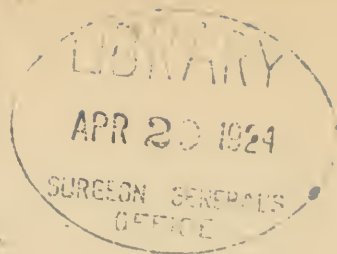
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A TREATISE ON ECHINOCOCCUS DISEASE*

INCORPORATING THE REPORT OF THE SECOND CASE OF THE DISEASE
TO BE REVEALED IN THE APE, *CYNOCEPHALUS PORCARIUS*

By E. B. HELLER, M.D.

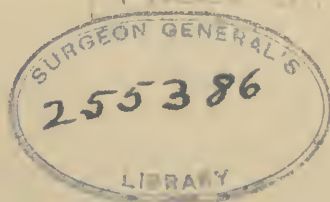
Kansas City

INTRODUCTION

ONE adds to the literature of echinococcus disease with a certain amount of trepidation, because the disease is relatively rare in these United States. Yet, paradoxically, there scarcely passes a month without a report in one of the current periodicals of an incidence of the disease. It has occurred to me that there does not exist in the English language a monograph of recent issue dealing with the diseases in all its phases. This, together with the fact that I have recently encountered (and reported) the disease in the post-mortem examination of an ape from the Kansas City Zoological Park,¹ stimulates me to the present effort. Inasmuch as I propose to review the subject in all its phases, I may be pardoned for including illustrations and descriptions of my case in conjunction with reviews and illustrations of cases in the human subject, collected from the literature.

Medical zoology and its relation to public health problems have received considerable attention of late years, both at home and abroad: Witness such pleas as that of Hegner,² a recent editorial in the *Journal of the American Medical Association*,³ the devotion of an entire week of the Second National Medical Congress of Argentina to a symposium on echinococcus disease from every possible standpoint, and the establishment at Cambridge University of an Institute of Animal Pathology to better coördinate the departments of medicine and agriculture in their fight against disease. If not the most important subject for study, echinococcus disease cer-

* The complete text of the Alvarenga Prize Essay of the College of Physicians of Philadelphia, awarded October 3, 1923, some previously published illustrations being omitted.



tainly furnishes one of the most interesting investigations with about equal significance to the lower animal world and the human.

When I say that the disease is relatively rare in the United States I am fully aware of the fact that many, many cases are never reported at all, or are reported before local medical societies and never get into the current periodicals. In talking with a number of busy surgeons of western Missouri and eastern Kansas, I was unable to find one who had not had one or more cases to deal with in recent years.

I am greatly indebted to Mr. Miles Standish, of Kansas City, for the interest and skill he has demonstrated in photographing my specimens and in preparing the prints. I am also indebted to Dr. Samuel Voegelin for the preparation of microscopic sections of the various organs, and for the interest he has shown in their study.

Mr. N. T. Clark, in charge of the Kansas City Zoological Park, intensely interested in the welfare of his *protégés*, has stimulated the interest of myself and others in the diseases occurring among the wild, and deserves all manner of praise from the people of our home city.

I wish also to express my greatest appreciation to Dr. C. E. Corlette, of Sydney, Australia; to Dr. F. Ware, of the Civil Veterinary Department, Madras, and Major R. Knowles, of the Indian Medical Service, Calcutta, for the courteous and thorough manner in which they replied to my inquiries.

DEFINITION

Echinococcus disease is an infection or infestation, visceral, somatic or both, with the larval *Echinococcus granulosus*. Man and about forty other mammals act as intermediate hosts, harboring the larval cycle of *Tania echinococcus*, or the "dog tape-worm." As the latter name implies, the adult stage is completed in the small intestines of the dog or some other member of the Canidae, being the intestinal infection (or infestation) in contradistinction to the somatic infection or larval cycle, which seems to require for its development tissues of an herbivorous or omnivorous host.

SYNONYMY ⁴

Genus ECHINOCOCCUS Rudolphi, 1801.

- 1782. HYDATIS Goeze, 1782a, 192; very doubtful whether this is used in a generic sense in synonymy.
- 1801. ECHINOCOCCUS Rudolphi, 1801, 52-53; includes *Tænia multiceps* (type of *multiceps*, 1782, and *polycephalus*, 1800) and *Tænia visceralis socialis granulosa* Goeze, 1782, hence it is a deliberate renaming of a genus for which two names were already available, but Rudolphi definitely mentions *Die körnigen Blasenwürmer* (namely *granulosa*) as basis of *Echinococcus*, hence this is the type species; see also *Rudolphi*, 1802, 204.
- 1804. ACEPHALOCYSTIS Laennec, 1804, 132, 134-135; 1812, 96-123, 130-155, 170-173; type apparently *Echinococcus granulosis*, by inclusion.
- 1819. LIOCOCCUS Bremser, 1819a, 249; type *Echinococcus hominis*, genus not adopted by Bremser, 1819a.
- 1819. SPLANCHNOCOCCUS Bremser, 1819a, 249; *Echinococcus* renamed, hence same type.
- 1821. ACEPHALOCYSTUS Laennec of Merat, 1831, 229; for *Acephalocystis*, 1804, hence same type.
- 1829. ACEPHALOCISTIS Cruveilhier, 1829a, 198; for *Acephalocystis*, 1804, hence same type.
- 1829. ?? ACROSTOMA Lesauvage, 1829, 433-438; hence only type species. *A. amnii*; probably pathological structure of *amnion*.
- 1844. ? ASTOMA Goodsir, 1844d, 282; only hence type species *A. acephalocystis* Goodsir.
- 1844. ? DISKOSTOMA Goodsir in Gairdner, 1844a, 276; only hence type species *D. acephalocystis* Goodsir.
- 1844. ? SPHAERIDION Goodsir; not accessible; see Gervais, 1847a, 92.
- 1856. ECHINOKOKKUS Bull, 1856a, 429; for *Echinococcus*, hence same type.

1858. ECHINOCOCCIFER Weinland, 1858, 52, 61, 85; type *Tænia echinococcus*.
1894. ? DISCOSTOMA Braun, 1894a, 982; for *Diskostoma* Goodsir, 1844, hence same type.

HISTORY OF THE PARASITE

It is thought by some that *Echinococcus* disease was known to Hippocrates. Mosler and Peiper in Nothnagel's "System of Medicine" make the following quotation from his writings: *Quibus jecur aqua repletum in omentum eruperit, iis ventu aqua impletur ac intereunt*.*

The earliest mention of the disease by modern writers is by Ruysch in 1721, when he described a condition which was undoubtedly *Echinococcus multilocularis*, as "Colloid cancer." Goeze, in 1782, was the first to use the term *Hydatid* to describe the condition although Stiles⁴ doubts whether he used the term in a generic sense.

The work of Batsch (1786), and of Rudolphi (1801-1805) established the type species *Echinococcus granulosus*, which terminology is largely used to-day. Considerable work was done by German investigators during the nineteenth century, and notable is the work of Leuckart, Küchenmeister and Virchow. It was Küchenmeister who, in 1851, demonstrated by feeding experiments that the cysts were only the larvæ of tape-worms, and that for a complete life cycle, two hosts were necessary.

The older writers frequently described the condition which was undoubtedly echinococcus disease, as an "alveolar colloid cancer." Sir Astley Cooper, in 1837, in describing cystic disease of the female breast, referred to it as "hydatid disease." Much confusion exists even up to the present, as to the proper terminology and classification. M. C. Hall, of the Bureau of Animal Industry of the United States Department of Agriculture, has done much to clear up the situation by compiling a very complete monograph dealing with adult tænioid cestodes of domestic carnivores of North America.⁵

The *multilocular* (also called *alveolar*) hydatid or echinococcus was first recognized and described by Virchow in 1855.⁶ In 1888

* "When the liver is filled with water and bursts into the epiploön, in this case the belly is filled with water and the patient dies."

FIG. 1.



Map showing distribution of echinococcus disease throughout the world

he established the fact that echinococcus disease of the liver and of bone are the same disease. He, moreover, recognized the fact that echinococcus of the multilocular and that of the cystic type are the same parasite under different conditions of life.⁷

Since 1901, many authors have aligned themselves with Melnikow-Raswedenkow,⁸ who stated it as his conviction that *Echinococcus alveolaris* occupied an intermediate position between *Cestodes* (tape-worms) and *Trematodes* (flukes), because of its power to produce amœboid embryos *in loco*. He also insisted that two species of the parasite were required to produce the two forms of the disease (cystic and alveolar).

The best opinion to-day, however, is in support of Virchow's early contention, *e.g.*, that but one species, commonly known as *Tænia echinococcus*, is the cause of the disease in its various manifestations. Stiles⁹ admits only one species, as does Corlette.¹⁰ The views of the latter author have been ably expressed, and his work stands at present as one of the best, if not the best, with reference to the etiology and pathology of echinococcus disease.

GEOGRAPHIC DISTRIBUTION

Echinococcus disease is cosmopolitan, that is to say, it is common to all the world, with a special predilection for the Temperate Zone, and a mild abhorrence for the tropics. (See map, Fig. 1.) Stiles says that Iceland is recognized as the classical Echinococcus Land. The disease is evidently of long standing there, for reports give the incidence as one to every thirty of the population (Galliot), and Krabbe reports 25 per cent. of the dogs infested with the *Tænia*. Iceland was settled by the Norsemen in 874. In view of the fact that Hippocrates is supposed to have known the disease, it would be interesting to determine whether or not the imported dogs and sheep brought the disease to the island in those early times. It would be a still more interesting study to seek out the original nidus from which the disease has spread throughout Europe, and *via* the trade-routes, through the medium of dogs, sheep, and other hosts, to North and South America, India, Australia, and South Africa. Australia and Argentina vie with Iceland for greatest incidence of the disease.

In the province of Victoria, Australia, records show that one out of every one hundred seventy-five (175) hospital patients is suffering with the affliction, while three in every thousand die of the disease. The Mt. Gambier Hospital records one echinococcus patient to every sixty-five admissions for all complaints. Corlette and others have called attention to the fact that human infection is relatively uncommon in the more tropical parts of Australia, whereas the incidence in animals is not affected. In a personal communication (January 28, 1923) he modifies his statement by adding that "...the population of tropical Australia is at the same time so scanty, and also much of the occupied country is cool tableland."

This latter observation is interesting in view of reports from India, where echinococcus disease has been found in 70 per cent. of the cattle (Friedberger and Fröhner), whereas the disease is rarely reported for human beings in India. A recent personal communication from Ware,¹¹ of the Civil Veterinary Department, Madras, India, confirms the figures of Friedberger and Fröhner "for the south of India." An interesting fact is that the workers in animal pathology have never recovered the *Tænia* from the native dogs of Madras, nor have they been able to infect dogs, although Ware states that they have made the attempt four times by feeding hydatids. If Ochsner's theory of cancer-infection is tenable, the methods of cooking food in India, besides warding off cancer of the alimentary canal, would incidentally safeguard the population from echinococcus disease.

For a similar reason, it would seem that the whole of southern Asia is protected. No considerable number of cases has been reported, yet with the advance of civilization in these countries, we may look for a penetration of the disease.

As has been stated, the disease is common in Europe, especially in Silesia and the mountainous districts of Austria. During the latter half of the past century, much of the work on hydatid disease was done in Germany because abundant material was available, and the disease had to be controlled for economic reasons. At one time the slaughter-house statistics gave the incidence of the disease as 10.39 per cent. for cattle, 9.83 per cent. for sheep, and 6.47 per

cent. for hogs. Madelung in 1026 autopsies (human), at Rostock from 1861 to 1883, found the hydatids in twenty-five cases.

Although comparatively few cases are reported from Greece, there must be a large morbidity from echinococcus disease inasmuch as Greek emigrants rank high among those suffering with the disease in America. Within a year (1921-1922) three young Greeks were operated on in various cities for advanced echinococcosis, to wit, a cyst of the liver by Da Costa, of Philadelphia; one of the right kidney by Kretschmer, of Chicago; and a case with two cysts of the liver by A. J. Welsh, of Kansas City. Greeks ranked second in number among the eighty-seven cases in North America collected by Magath.¹² The tendency of these people to operate restaurants and fruit stands would render them dangerous to the community were the disease more readily transmitted. (See table, page 261.)

In North America cases have been reported from every section, for the most part north of the thirtieth parallel. The disease is said to be endemic in some sections of Canada, notably Manitoba, which province is inhabited by numerous Icelanders. Ferguson has operated upon many of these people for the disease (Osler). Epidemics have occurred among hogs in Virginia, Wisconsin, Arkansas and Oklahoma. At least in the case of Virginia, Johnston and Willis¹³ have shown a direct connection between the epidemic in the hogs, and a subsequent epidemic among human beings.

At one abattoir in Kansas City, in 1904, infection in hogs was reported as one per cent. (Stiles). No doubt indigenous cases have occurred in man which have not been recognized. All of the surgeons of experience, in Kansas City, have had one or more cases of the disease come to them from adjacent territory. Johnston and Willis state that only 250 cases were reported in the United States up to 1913. Including cases reported in animals, the number far exceeds this figure for the subsequent period. Some of our large hospitals and clinics report numbers of cases—thus, at the Massachusetts General Hospital, Davis and Balboni¹⁴ recently analysed the records of twenty-nine cases (1875-1916), while there have been twenty-five cases at the Mayo Clinic in as many years (Magath¹²). Corlette¹⁵ says that he has “always found it puzzling to account for the scarcity of hydatid disease in the United States.” In his

paper (*loc. cit.*) he alludes to another puzzle: ". . . its rarity among the human inhabitants of India while at the same time there is ample evidence that it is extremely common in the domestic farm animals of that country. The immunity of man in India is therefore not due to absence of the echinococcus from the country, nor can it be due to sanitary precautions on the part of the native, who does not in the least object to the use of fecalized water, patronized by dogs." This last statement would cast some doubt about Ochsner's statistics and theory.

The disease is so prevalent in the temperate portions of South America, that considerable research has been stimulated. For instance, some of the first work on the complement-fixation test as applied in the diagnosis of hydatid disease was done by Apphatie and Lorentz¹⁶ in Argentina, as far back as 1908. From October 1 to 8, 1922, the Second National Medical Congress of Argentina devoted all of its time to a discussion of the disease. The city and province of Buenos Aires had 89 per cent. of the 2740 cases of the disease treated surgically in the past eleven years in Argentina. The proceedings of this convention would be well worth reading to anyone interested or to one who doubts the positive danger from the disease. In 1910, 5 per cent. of the sheep and cattle were found infected. Now, 30 per cent. of the sheep and 15 per cent. of the cattle are infected.

That the disease is present in South Africa, is evident from case reports, and from the fact that the disease has even penetrated the neighboring wilds. My case is the second reported in apes from the wilds of South Africa, the first having been reported by Nicoll,¹⁷ of Lister Institute, London, in 1918, in an animal of the same family and genus (*Cynocephalus porcarius*) as my own. This is interesting in view of the fact that Weidman,¹⁸ in a personal communication, states that in more than 5000 autopsies performed at the Philadelphia Zoological Gardens in the last fifteen years, the disease has not been met with in monkeys. On the other hand, he states that they have met with a few cases of *Cysticercus tenuicollis* in monkeys, and that it appears to be rather common in the wild.

According to Rivas¹⁹ *Tania echinococcus multilocularis* is not reported for Iceland and Australia. Corlette, however, with his wide experience with the disease in Australia, maintains that both

the multilocular and the granulosus types are present, that they are nothing more than the same parasite under different conditions of life, and that the former is the result of intensive exogenous budding, while the latter is the result of endogenous budding, or at least of failure to produce daughter-cysts by exogenous budding from the onchosphere. Further, he shows that both varieties may occur in the same host, and in the same echinococcus cyst. It may therefore be assumed that equally experienced investigators in Iceland would find similar conditions prevailing there. One is forced to agree with Corlette after a review of the literature, and in doing so subscribe to the contentions of Virchow, who, in 1844, stated it

Table Showing the Nativity of Patients with Echinococcus Disease Reported from North America (Magath)

	Before 1902 (Lyon-Magath)	Since 1902 (Magath)
Iceland	58	5
Germany	23	9
Italy	19	19
England	14	3
Ireland	3	4
France	3	0
Russia	4	6
Syria	2	1
Argentina	1	2
Azores	1	0
Austria	1	2
Denmark	1	0
Japan	1	0
Mexico	1	0
Sweden	1	1
United States	5	6
Canada	2	2
Negro (nativity unknown)	6	0
Greece	0	17
Turkey	0	1
Armenia	0	5
Roumania	0	1
Spain	0	1
Albania	0	1
Wales	0	1
Other foreigners	3	0
	<hr/> 149	<hr/> 87

Table Showing the Organs Affected in Cases Reported After 1902 (Magath)

Organs	Cases
Liver	69
Peritoneum	10
Lungs	4
Kidneys	4
Omentum	4
Spleen	2
Retroperitoneal	2
Spinal cord	1
Brain	1
Abdominal wall	1
Gall-bladder	1
Common bile-duct	1
Uterus	1
Neck	1
Tibia	1
Pleura	1
	<hr/> 104

as his belief that both types of cyst formation were manifestations of the same parasite under different conditions of life. Thus, compression in the case of bone has the same effect, but to a greater extent, as has the pressure of Glisson's capsule on the individuals in the liver, etc.

According to M. Simon,²⁰ echinococcus disease is endemic in man in Sweden. It is also quite prevalent in Norway.

ZOOLOGICAL DISTRIBUTION

The adult worm, *Tænia echinococcus*, is found to inhabit the upper small intestine of the dog, wolf, and other *Canidæ*, the most common hosts being: *Canis familiaris*, *C. lupus*, *C. aureus*, *C. dingo*, *C. mesomelas*, *Felis catus domestica*, *F. concolor*. The parasite prefers an alkaline medium, and therefore is seldom found in the first portions of the duodenum of the primary host, but in the terminal portion, and in the upper jejunum. Here large numbers are often found adhering to the villæ. Their small size renders them difficult of detection unless they are especially looked for.

The larval stage occurs in practically every organ and tissue of the secondary host. The liver is the organ involved in more than 50 per cent. of cases, either alone or coincident with involvement of

other organs. The lungs are involved in about 10 per cent. of cases; the kidneys, 10 per cent.; muscles, subcutaneous tissues and bone in 10 per cent.; the central nervous system, 5 per cent., and the spleen and other tissues in 15 per cent. The embryos seem to prefer loose cellular tissue, and in the case of the large vascular organs as the liver and spleen, they develop close to the surface, in the subserosa, and as they grow, present about 20 per cent. of their contour beyond the surface of the invaded organ.

The following list includes all the principal secondary hosts: *Homo sapiens*, *Bos taurus*, *Ovis aries*, *Capra hircus*, *Sus scrofa domestica*, *Sus scrofa*, *Pithecus species* (*Simia cynomolgus*), *Pithecus silenus* (*Simia silenus*), *Simia sylvanus* (*Simia inuus*), *Cynocephalus porcarius*, *Ovis ammon*, *Camelus bactrianus*, *C. dromedarius*, *Giraffa species* (*Camelopardalis giraffa*), *Tetracerus quadricornis*, *Alces alces*, *Equus caballus*, *E. zebra*, *E. asinus*, *Tapirus indicus*, *Canis familiaris*, *Felis catus domestica*, *F. pardus*, *Macropus major*, *Sciurus vulgaris*, *Mungos ichneumon* (*Herpestes ichneumon*), *Simia sylvanus* (*Inuus ecaudatus*), *Macropus giganteus*, *Ovis argali*, *Tapirus americanus*, and *Oryctolagus cuniculus* (*Lepus cuniculus*).

It will be noted from the above that several of the animals harbor the parasite in both the larval and the adult cycles, in fact the same animal may on occasion be the host of both cycles. More extensive research will probably prove some of the above animals to be the victims of a cysticercosis, the difference between the various bladder-worms being but poorly understood by some of the older investigators.

THE PARASITE

Tænia echinococcus, Siebold, 1853. (Type, *Vermes*; class, *Plathelminthes*; order, *Cestodes*; family, *Tænia*; group, *Tænia vesicular* or *cystica* of Leuckart.)

The best authorities, as has been said, at the present time admit only one species, *Tænia echinococcus* (Zeder, 1803; Siebold, 1853). If, as suggested by Weinland, the species be placed in a distinct genus, the name would be *Echinococcus granulosus* (Batsch, 1786; Zeder, 1803; Rudolphi, 1805). For the sake of simplicity in explaining the pathology as presented in various organs of various

hosts, in various parts of the world, it is probably best to divide the genus into two species as suggested by Rivas:¹⁹

(a) *Echinococcus granulosus*, or *Tænia echinococcus unilocularis*.

(b) *Echinococcus multilocularis*, or *T. echinococcus multilocularis*.

Tænia echinococcus is one of the smallest tape-worms known, being four to five millimetres long. The head is very small, subglobular, and about 300 microns in diameter. The rostellum is rather prominent, and is armed with a double row of hooklets, 28 to 50 in number. The large hooks are 22 to 30 microns in length, and have a blade of very slight curvature, which tends to lie in a prolongation of the longitudinal axis of the handle, and which is very thick at the base. The handle is straight, short and thick, with dorsal and ventral swellings in the median portion. The guard is very short, is rounded, and forms a hemispherical protuberance. The smaller hooks are 18 to 22 microns long, with a very short and slightly curved blade which lies in a prolongation of the longitudinal axis of the handle; the handle is comparatively long and narrow with a prominent dorsal swelling near the middle, which causes a tapering to the distal extremity. The guard is relatively quite large and oval in outline. The suckers are on the average 130 microns in diameter and are set well back from the rostellum. The neck tapers posterior of the suckers, and then gradually expands to meet the anterior margin of the first segment. The first segment is almost square, being about 240 to 260 microns long and wide, and is devoid of generative apparatus. The second segment is about twice as broad in its posterior portion as the first segment, and is about four times as long. It contains generative apparatus. The third segment is gravid, and comprises about one-half the length of the entire strobila, being about 2 millimetres long. The maximum width is attained just caudad of the genital pore, being 600 microns. The longitudinal excretory canals are visible and often contain calcareous corpuscles.

Male Genitalia.—There are about 50 testes to each of the mature segments. They are 70 microns in diameter, and are situated for the most part in the ends of the segment and opposite the genital

pore. The vas deferens originates near the median line of the segment on the poral side of the median stem of the uterus, and anterior of the ovary. There are found several wide coils before the distal portion emerges into the genital pouch, which latter is about 500 microns long and extends into the segment almost to the median line.

Female Genitalia.—The ovary is horse-shoe shaped with a median isthmus narrower than the ends, and the concavity posterior is submedian in position and about half-way between the plane of the genital pore, and the posterior border of the segment. The vitellarium is situated near to the posterior border of the segment and consists of a dorsal and a ventral lobe, which lie one above the other, and are formed of two portions each with its own duct. The shell-gland is spherical to oval. The ovaries, vitellarium and uterus have the common openings of their tubes within the shell-gland. The vagina has a large, elongate, setose dilation about 50 microns in diameter near the genital pore and bends at an obtuse angle mesad of this to extend posteriorly and mesially to a receptaculum seminis about 14 microns in diameter. The uterus develops comparatively late, forming a median stem and lateral enlargements, the outlines of these later becoming quite distinct. The eggs are 32 to 36 microns by 25 to 30 microns in diameter (Hall).

LIFE CYCLE OF THE PARASITE AND MODES OF INFECTION

The ova of the parasite are discharged with the faeces of the primary host, and are taken into the alimentary canal of one of the secondary hosts with food or water. Here the six-hooked embryos escape from the shell and burrow through the wall of the intestine—many finding their way into the portal system or lymphatics; and doubtless some migrate up the biliary passages into the liver and gall-bladder. Johnston and Willis¹³ contend that eggs which become attached to dust particles, and which are inhaled by a suitable host, develop into cysts in the lungs of that individual. I have been unable to find any other writers on the subject of echinococcus disease who give air-borne infection of the lungs any place. Normal mucous membrane of the respiratory tract would hardly be able to furnish the necessary solvents of the shell of the embryo,

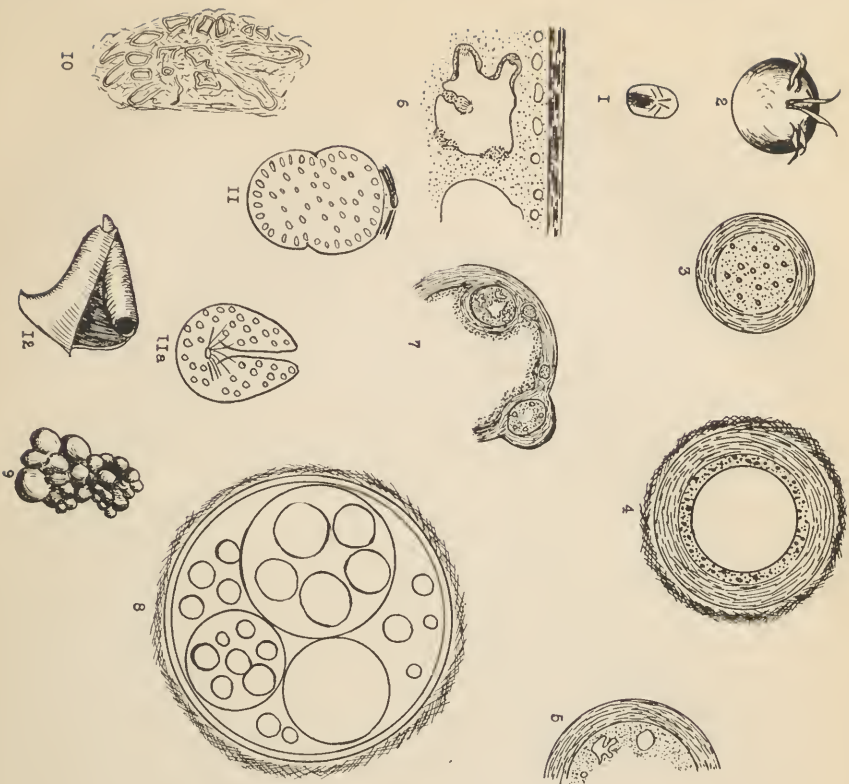
which must precede its liberation. In spite of the fact that there is no authentic record of infection of the lungs direct from contaminated air, such an event *might* possibly occur, in view of the fact that Hutchings²¹ and others have demonstrated the development of hydatid cysts following the direct implantation (on denuded surfaces) of the ovum of *Tænia echinococcus*. That the scolices and brood-capsules are capable of developing cysts when sown upon suitable soil has been abundantly shown in cases of rupture of mother-cysts either at surgical operations or spontaneously—the scolices being liberated into the peritoneal cavity or upon the raw edges of the wound—developing cysts where they have become attached. Then, too, the reported cases of echinococcus cysts, primary of the lung, with no other apparent visceral involvement, lend force to the argument in favor of air-borne infection.

When the disease is widespread in the body of the secondary or intermediate host, the term *echinococcosis* is applicable, and the process is known as *hydatidization*. Given embryos which have been liberated from their shells by the solvent action of the digestive juices of the secondary host, the following tabulation represents some of the possible eventualities:

Hydatidization.—(1) Direct or primary implantation of embryos as emboli, in the various organs of the body, *i.e.*, liver, spleen, heart, lungs. (2) Indirect, or secondary implantation of scolices or brood-capsules as emboli in various tissues of the secondary host. (a) Inoculation of the peritoneal cavity, pleural cavity, etc., by rupture into them of a fertile cyst, brood-capsules being sown upon the serosa. (b) Embolization of lungs, heart, brain and other extra-abdominal organs by fertile cysts or scolices from a primary or secondary colony in an abdominal organ or in bone. (c) Propagation, by exogenous budding, or growth of individuals of a colony in one organ, into an adjacent organ or tissue. (3) Infection of another individual through the ingestion, implantation, or inhalation (?) of fertile cysts or viable scolices.

The adult stage is not necessary for the transmission of the disease, epidemics having been reported in man due to the eating of infected organs of sheep or hogs, and in hogs, due to the eating of infected organs of sheep, and so on.

FIG. 2.



DIAGRAMS OF LARVAL CYCLE; ECHINOCOCCUS GRANULOSUS.

(AFTER MOSLER and PRIPER, STEWART, LEUKART, ZIEGLER, and LENDON)

1. Cyst, about 0.01 mm. in diameter, showing six-hooked embryo.
2. Embryo free from its shell.
3. Cyst differentiated into outer laminated layer and parenchyma.
4. Acephalocyst stage. An outer laminated layer and an inner parenchymatous layer, both now vascular, enclosing fluid.
5. Showing development of Brood-capsules.
6. Showing in some detail, a cross-section of the cyst-membrane, also the parenchyma containing one complete brood capsule, with developing Scolex or tape-worm head.
7. Developing daughter cysts, showing one which might easily bud externally.
8. Daughter and Grand-daughter cysts
9. Mass of small Daughter-cysts, mother-cyst having disappeared.
This type is most common in bone.
10. Shrinkage of mother cyst, causing parasitic wall to be folded, and between these folds is vascular fibrous tissue belonging to the adventitious cyst, the whole forming a semi-solid or solid mass, having a honey-comb-like foliated appearance on section, compared to the heart of a cabbage, or resembling ooloid cancer.
11. Scolexes, with rostellum and hooklets protruded or retracted(a) like a vorticella. - Just visible as specks when the fluid is held up to the light. - measuring about 0.3 mm.
12. Section of echinococcus membrane with curled in edges.

Although most embryos enter the portal system from the villæ of the upper small intestine, there is ample evidence that some enter the lymphatics, and still others enter the peritoneal cavity by traversing the entire thickness of the wall of the gut. Then, too, there is proof that some embryos enter the ampulla of Vater, and proceed upward into the liver and gall-bladder. Once having come to rest in a venous, biliary, arterial, or lymphatic radical, the hooks disappear, and the embryo develops into the larval stage, a bladder-worm (Fig. 2).

The growth is very slow, Leuckart in his experiments on swine, having demonstrated that it requires five months for a cyst to become 15 to 20 millimetres in diameter. If the cyst or cysts are not in such position as to interfere with vital functions, the growth is often very great, cysts the size of a child's head having been reported. The bladder-worm is called an *echinococcus* or *hydatid*, and is characterized by the development of two layers, an outer laminated layer or cuticular membrane, and an inner, finely granular layer, the parenchyma of the cyst. The outermost covering of the cyst is usually fibrous tissue derived from the invaded organ. The wall of the cyst is normally pearly white, and fairly tough. It is chemically described as *chitin*, or a substance between chitin and the proteins (Hammerstein).

When the cyst attains the size of two centimetres in diameter, or more, conditions of life being favorable, daughter-cysts develop from the parenchyma or internal germinal membrane (Fig. 2). These may project into the mother-cyst where they appear as dot-like bodies, or they may project outside the cyst and there form external daughter-cysts. The former process is called endogenous budding, and the latter, exogenous budding. Both varieties may occur in the same cyst. The daughter-cysts grow, and in due time give rise to granddaughter-cysts, and so on *ad infinitum*. In any cyst of the series, brood-capsules may be formed. These latter are bladders which contain scolices. In many cases the entire series of cysts are devoid of brood-capsules, and no scolices or hooklets are found in the contained fluid. Such a condition is usual in cysts of bone, and in very old cysts. When brood-capsules or the contained scolices are ingested by the primary host, the heads develop segments

and form adult (strobilate) worms which assemble in the upper portion of the small intestine, and the cycle repeats itself. Leuckart showed that scolices fed to dogs require ten to twelve weeks to develop into the adult worm, and reach the gravid stage.

PATHOLOGY: ORGANS INVOLVED

Under this heading the disease as it manifests itself in man will be considered, and the disease in the primary host, which has been dealt with under "zoological distribution," will be further discussed under the heading of prophylaxis. The number of lesions depends largely upon the number of ova ingested. That is to say, barring accident en route, each and every ovum ingested by a suitable host (secondary or intermediate), should ultimately come to rest as a six-hooked embryo in the terminal radicals of one of the organs of the body. Here the embryo's identity is obliterated as it develops into the cyst containing clear fluid.

As has been stated, no organ or tissue of the body seems to be exempt from the visitation of the embryo, but the liver, because of its position and function as recipient of the portal blood, and its direct communication with the duodenum, is more often involved than all the other organs of the body put together—over 50 per cent. of cases. The lungs are involved in about 20 per cent. of cases, the kidneys in about 10 per cent., the muscles, subcutaneous tissues and bone in 10 per cent., and the central nervous system in about 5 per cent. of cases, while the spleen and the remaining tissues are affected in about 15 per cent. of cases. The cysts are very prone to develop in the loose cellular tissue and in the subserosa.

If growth is unobstructed, the tendency is to rupture eventually from the tension of the accumulated fluid, or from necrosis of a portion of the cyst-wall due to pressure of the daughter-cysts. Another mode of termination is to cease to grow, because of pressure from without, or lack of nourishment, the onchosphere and all its contents then shrivel up, and assume a putty-like appearance, perhaps later becoming impregnated with calcium salts.

When cysts are contiguous to hollow viscera, the mutual pressure causes an absorption or necrosis of the intervening tissue, and a rupture of the cyst results in an evacuation of its contents into that

viscus. Instances of such accidents will be mentioned in subsequent paragraphs. On the other hand, if the intervening tissue withstands the pressure, other possibilities are that gases or fluids will osmose through the membrane and kill the parasite, or that suppuration will ensue upon the entrance of pathogenic bacteria into the cyst.

Liver and Gall-bladder.—The effect of echinococcus cysts of these organs vary with the situation and size of the cysts. There may be a single cyst or there may be many cysts in a given case. The museum of St. Thomas's Hospital in London contains a liver removed at autopsy from a sailor, which weighs twenty-five pounds and is thoroughly infested with echinococcus cysts. In the liver as in other organs of the host, the embryo invades the loose connective tissue in which the hepatic vessels and ducts are located. The liver parenchyma surrounding the cysts shows the results of irritation, by the development of a fibrous tissue investment, and as the cysts increase in size, adhesions are formed to neighboring viscera as a result of the localized peritonitis. Both the multilocular and the granulosus types of the larva are found involving the organ, and the two types have even been reported in the same organ. Taken by and large, however, the granulosus, or unilocular cystic form is most common in man, while the multilocular type is found in the lower animals. This latter fact is used by Corlette¹⁰ as a very potent argument against the two-species doctrine: "... if there are two species of parasite required for the two forms of hydatid disease, the multilocular species must be abundantly domiciled in South Australia, even though in the human beings only the cystic form has seemed to find a place." Neisser²² in his observations reported the following complications of echinococcus disease of the liver:

- 47 ruptured into lung and pleural cavity,
- 46 ruptured into stomach and intestines,
- 16 ruptured into the peritoneal cavity,
- 15 ruptured through the abdominal wall.

Suppuration is the most common accident, and when it occurs, the clinical picture changes to one of sepsis, and the cyst contents gradually become disintegrated and lose their identity. In addition

to these complications, numbers of instances are on record of the rupture of cysts into the common or hepatic ducts, and even into the inferior vena cava. Fowler, in 1916, reported a case of cyst of the left lobe of the liver which ruptured and discharged its contents into the left hepatic duct. A case combining many of these features was recently reported by Major H. W. Jones²³ of a young private in the medical department of the United States Army, of Italian birth, who died some weeks after a laparotomy during which the diagnosis was made. There were multiple cysts of the liver, multiple abscesses of the liver, a right empyema communicating with an abscessed cyst of the liver; the common duct contained cyst-membrane, hooklets, and one small unruptured cyst; the hepatic ducts also contained unruptured cysts.

In addition there was a cyst of the spleen with considerable enlargement of that organ. Another interesting feature was the absence of eosinophilia, a frequent occurrence, yet a point which confirms the observations of those most conversant with the disease, *e.g.*, eosinophilia is frequently absent, and whether present or absent is of little diagnostic aid.

Phemister²⁴ several years ago reported a case with cysts of the liver, complicated later by subphrenic abscess, pyopneumothorax, and hydropneumothorax. Vegas and others have reported cases of hydatid pyopneumocyst of the liver. A case has recently been reported by Shaw of a suppurating echinococcus cyst of the liver, with multiple abscess formation, which recovered. When the multilocular type of cyst is present, the infiltration is usually very rapid, a feature which has led to its appellation: "Malignant hydatid." In this type the liver-cells have not time to proliferate and the organ to undergo the usual compensatory hypertrophy, with the result that it is destroyed by the rapid growth of the cysts.

Cysts found in the gall-bladder may mean primary infestation from the duodenum or rupture of a primary cyst of the liver into it or into one of the biliary ducts. Thirteen cases of hydatid cyst of the gall-bladder have been reported in Argentina according to Gutiérrez.²⁵ In several instances cysts and calculi have co-existed.

Allende and Tobias²⁶ record an interesting case of intermittent

hydrops of the gall-bladder due to pressure on the ducts of a suppurating hydatid cyst of the liver.

Cirrhosis of the liver plus echinococcus cysts gives a distorted picture, at times. Thus, Taboada²⁷ reports a case of atrophic cirrhosis of the liver which resembled a hypertrophic cirrhosis with ascites, and which was not definitely diagnosed until autopsy revealed a complicating hydatid cyst. The ascites required frequent tapping for a while, but ultimately subsided. The case was under observation a total of two years.

Spleen.—Echinococcus cysts are the most common form of cysts of the spleen (Moynihan), and the only parasitic type reported in the literature to which I have access. Trinkler found the spleen affected in 68 of 2117 cases of the disease. As a rule other organs are involved as well. In my own case (Figs. 3 to 7) it was impossible to determine which were the older, the cysts of the liver, or those of the spleen. As is usually the case, the lower pole of the organ contained the cysts in my specimen, and the lower one projected over the splenic flexure of the colon. These were of the unilocular variety—a fact worth recording inasmuch as so few cases are reported for apes, and because the multilocular type is said to be more common in the lower animals.

Murchison describes a case of echinococcus cyst of the spleen rupturing into the colon. The unilocular cyst is the type usually reported for the spleen in the human being. Infection of the spleen may be by the way of the portal or systemic circulations, probably the former in the vast majority of cases. In this location the cysts are subject to the same accidents as are cysts of the other abdominal organs. Like the liver, the spleen undergoes hypertrophy to compensate for the parenchyma displaced by the cyst or cysts.

Heart.—Echinococcus cysts are not rare in this organ. The parasite selects the loose areolar tissue of the auriculo-ventricular groove, and then may bulge into the adjacent cavities. The cyst or colony of cysts may cause death by interfering with the action of the heart, or by rupturing into one of the adjacent cavities, from whence daughter-cysts, membrane or detritus is carried into the pulmonary or systemic circulation (Bland-Sutton). H. W. Mills,²⁸ of San Bernardino, California, reports an interesting case

in a French woman of a hydatid cyst in the wall of the right ventricle near the apex, five centimetres in diameter, and with four cysts in the right lung. In his bibliography he enumerates no less than sixty authors who have reported cases of echinococcus cysts of the heart and pericardium. His case was diagnosed at autopsy as is usually the case. Rarely cases are diagnosed during the life of the patient. One such case is recorded in the *Medical Journal of Australia* (April 9, 1921) by Martin and De Crespigny where the fluoroscope revealed a rounded opacity behind the sternum which pushed the heart to the right and which was about the size of a "fetal head at term." Exploratory puncture confirmed the diagnosis but probably contributed to the fatal issue, for two weeks later the patient died suddenly in collapse. Autopsy proved the diagnosis. The principal cyst, an old one, appeared to be attached to the apex of the heart and to bulge through the pericardium, displacing the left lung upward. A second, smaller cyst arose from the right ventricle.

The fact that numbers of cases of hydatid cysts of the heart occur in subjects with no other involvement, suggests that the original embryo, after entering and passing the hepatic and pulmonary circulations, lodges in the heart wall. The development of the cyst is disturbed by the motion of the heart, and therefore early rupture is common. Metastatic cysts develop in the brain, lungs or elsewhere depending upon the site of rupture, and providing, of course, it is not in itself a fatal catastrophe. It is hardly possible that cysts are engrafted into the pericardial sac and heart from the lungs and mediastinum. These regions are usually proved to be secondarily involved.

Lungs.—In this situation, while most often single, and in the right lower lobe, echinococcus cysts have been reported in both lungs simultaneously, in other lobes, and as multiple cysts, to say nothing of the complications. The two conditions under which the disease is found in the lungs are: (a) Entirely within the lung, arising within the lung, and (b) as extensions into the lung from the mediastinum or from beneath the diaphragm, propagation from colonies in the liver, lesser omentum, etc.

In the first instance, entrance is usually gained by way of the blood-stream—brood-capsules, primary embryos or scolices having

FIG. 3.



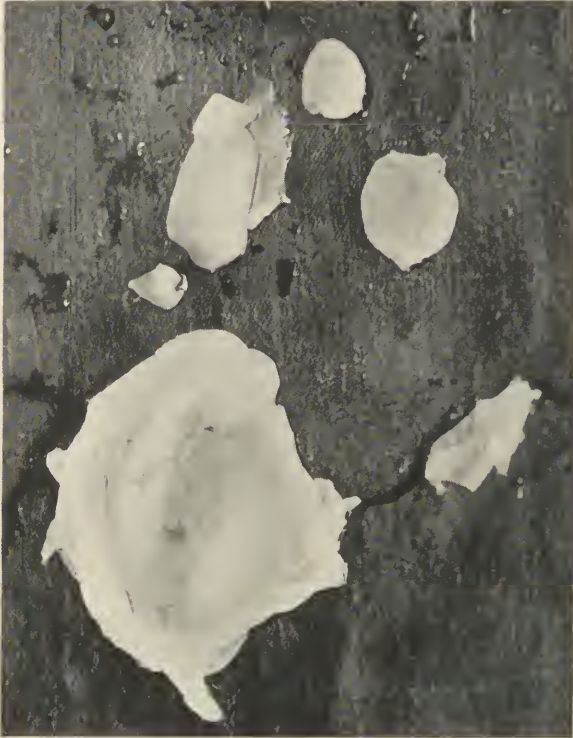
Author's case of echinococcosis in an ape (*Cynocephalus porcarius*). The cysts shown occupy most of both lower pulmonary lobes. Collapsed cysts are shown exuding from the incisions through the parenchyma. Microscopically, the latter showed patches of broncho-pneumonia. The adventitia was very poorly defined, being practically the compressed lung tissue. The pathology is identical with that found in the human subject.

FIG. 4.



Left: Two cysts of spleen of an ape (*Cynocephalus porcarius*). The contents of the upper one have been partially evacuated in order to show the thickness of the cyst-wall. Collapsed daughter-cysts are shown exuding from the opening made in the cyst at the lower pole. Right: Two cysts adherent, as removed from the lesser omentum. The lower one has not yet been opened.

FIG. 5.



Portions of cyst-membrane and collapsed cysts from the Author's case. The smallest mass is from the lung, and consists of a number of thicknesses of cyst-membrane matted together, and is of the consistency of the white of a very hard-boiled egg.

FIG. 6.



Liver of ape with echinococcosis, showing collapsed cyst exuding from a large cyst on the upper surface of the organ and one between the right and left lobes from which section has been taken. (Author's case; *Cynocephalus porcarius*.)

FIG. 7.



Liver showing one partly evacuated cyst on the superior surface, and one unopened cyst which was adherent to the inferior vena cava and the retroperitoneal structures. The upper cyst might have been approached through the pleura, but the lower cyst could never have been removed surgically, nor could its presence have been determined in routine exploration of the abdomen.

entered a remote vein, or the afferent pulmonary circulation. That this type of infestation of the lung occasionally follows fracture of a hydatid-infested bone, adds confirmation to the work done by Fritsche, Caldwell and Huber,²⁹ and others on fat embolism after fracture of long bones; in this instance, tiny cysts or scolices take the place of fat-embol. In a previous paragraph the improbability of air-borne infestation has been discussed. In the case of propagation of cyst-colonies from contiguous structures, what has been said for cysts extending into the lungs from the liver will suffice to illustrate the process.

Small cysts cause little inconvenience. Large cysts or multiple cysts, however, cause compression of the lungs, give rise to hemorrhage, and, on rupture, may cause death from suffocation: The membrane or cysts occluding the bronchi, or the fluid causing drowning. If, on the other hand, a fatal issue does not follow the rupture of a cyst, the fluid, membrane, daughter-cysts and scolices may be expectorated. The resulting cavity in the lung parenchyma usually becomes infected secondarily, and soon the picture of lung abscess is superimposed upon echinococcosis.

In the case of the ape reported by the author, death was probably due to suffocation following rupture, for a fit of coughing preceded his demise, and at autopsy, detritus from the cyst in the lower left lobe was found in the communicating bronchi. The cyst of the right lower lobe was still intact, and contained many collapsed daughter-cysts, some of them undergoing calcareous infiltration. Both cysts were adherent to the diaphragm, and portions of that structure had to be removed with the lungs, so dense were the adhesions. It is entirely possible that this is an instance of the extension through the diaphragm by way of the veins of the round ligament, and radicals which anastomose with the phrenic veins. Microscopic sections of the lung from areas near the cysts showed patches of broncho-pneumonia, and it is of course possible that this condition, and not suffocation, as was originally thought, was the actual cause of death. It may be said here that it is very difficult, in sectioning specimens of lung tissue, to include the cyst, as the development of the ectocyst is very slight, and there

is almost no attachment between it and the outer laminated layer of the true cyst.

Cases have been reported of echinococcus cysts which have compressed the lung tissue as they enlarged, gradually displacing the heart and other mediastinal structures. Bulging of the chest-wall and displacement of abdominal organs is still a later stage of the process. Rupture may occur into the bronchi, pleura, pericardium, great vessels, or through the chest-wall. Often, in the case of rupture into the bronchi, no harm seems to result, even though the cyst be a huge one, and unless other cysts are present, complete recovery follows. However, Cordier³⁰ recently studied five cases of pulmonary echinococcosis in which after rupture of the cysts and consequent injury to the parenchyma, either pneumococcic or tuberculous infection set in. He considers this form of infection rather unique. Authors have repeatedly stressed the clinical resemblance between hydatid disease of the lungs and pulmonary tuberculosis and broncho-pulmonary spirochetosis.

Pancreas.—Echinococcus cysts of this organ are extremely rare. Masseron,³¹ a decade ago, was able to collect only five cases from the literature. Recently, Albo, of Montevideo, Uruguay,³² published an excellent article on hydatid cysts of the pancreas with a review of a number of cases from the literature. He quotes statistics of Neisser to show that no case was found in 983 patients showing the disease elsewhere in the body. Also: "Feichman, among 2452 cases found only three, two of which were taken from the English literature and one from Russian" . . . He could not find more than twenty-four cases in the literature of all periods, and states that probably some of these are not genuine. I am unable to find a case recorded which was diagnosed before autopsy or operation.

From an experimental point of view, most authorities agree that the factor of safety is high, in that two-thirds of the pancreas can be removed in an otherwise normal individual. It is therefore safe to assume that replacement of two-thirds of the substance of the gland by echinococcus cysts, other things being equal, would not be fatal in itself. Graham, of Sydney, Australia, observed a hydatid cyst three inches in diameter which had replaced the head of the pancreas. Allen, Sweet, and others have shown that a rela-

tively small mass of normal island tissue can prevent the development of diabetes in dogs. Chutro (quoted by Albo) states that in the presence of hydatid cyst there are no microscopic signs of sclerosis or congestion of glandular tissue. No cases of rupture of the cyst into the digestive tract or elsewhere have been observed. Biliary and pancreatic obstruction have been reported in cysts occupying the head of the organ. As might be expected, the signs of the disease in the pancreas are not peculiar to this affection alone, but are those of any mass occupying this organ. An exceptional case is reported by Chaud³³ in the *Indian Medical Gazette*, of a child four years of age, whose pancreas (?) had been removed two years before with a large cyst of the organ, and whose urine has always remained free of sugar.

Kidneys.—Many cases of echinococcus disease of the kidney have been reported. Cysts are almost invariably present in the liver at the same time. The left kidney seems to be more often affected than the right, although the involvement is at times bilateral. The cyst may grow in the perirenal connective tissue or beneath the true capsule. Many attain very large size, some extending upward have been reported as rupturing into the bronchi. Roberts (cited by Ransohoff, "Keene's Surgery") states that in a review of sixty-five cases, he found fifty-two cases of rupture into the renal pelvis. In the latter instances, fluid, vesicles and cyst-debris flowed down the ureter and were discharged *per urethram*. In these cases diagnosis is of course a fairly easy matter, and this is often a satisfactory but painful mode of termination. When the cysts are very small, they occasion no distress, and are found only at autopsy. When large, a pyelogram may give a clue because of distortion or depression of the calyces.

Kretschmer³⁴ quite recently reported the eighteenth case of renal hydatid occurring in the United States and Canada in the entire period prior to 1923. As is the case with most other organs, the infection in the kidney may be of two types: (a) Primary, in which thorough examination fails to reveal involvement of any other organ, and (b) as a part of a generalized echinococcosis. Although statistics of various authors differ, it may be said that the kidney is involved in about 1 per cent. of cases of the disease.

Kretschmer's case was of the primary type, and was in a young Greek. His report is interesting and complete and valuable reading to anyone seeking information on renal hydatid.

Where there are any symptoms, hematuria, the passage of cysts or debris, and a urine of low specific gravity are almost constant. Fullerton,³⁵ in a study of "unilateral diuresis," reports an unusual case of hydatid of the kidney in which the urine from the sound kidney was normal in character and small in amount, while that from the ureter of the affected side was "watery, opalescent, neutral in reaction, had a specific gravity of 1005, and contained a trace of albumin, a few leucocytes, ureteral epithelium, an occasional red cell, but no hooklets."

Ductless Glands.—The disease is rarely met with in these organs. When affected, the mode is either by direct hematogenous implantation of embryo or brood-capsule, or by extension from a colony in a neighboring tissue.

Mammary Gland.—A number of cases of echinococcus disease of this gland have been recorded in the literature. For a time there was much confusion owing to an error on the part of Sir Astley Cooper, who, in 1837, referred to cystic disease of the breast as "hydatid disease." Instances are on record of the existence of colonies of cysts in the breast for periods as long as ten years, the parasites causing no inconvenience. A cyst in this gland may attain the size of a child's head (Bland-Sutton). Finney states that in the young, the disease is usually diagnosed as a benign tumor, while in the aged, the pre-operative diagnosis is usually given as carcinoma. Le Conte, in 1901, reported a single case and was unable to find another in American literature.

Uterus and Adnexa.—In this situation echinococcus cysts are usually observed growing beneath the peritoneum, and usually as a part of a general invasion of the subperitoneal tissues. Growing beneath the peritoneal investment of the uterus, the cysts are usually pedunculated, and resemble subserous fibroids. The most common point of infection is the pelvic cellular tissue between the folds of the broad ligament. In this situation, as they enlarge they are prone to involve the uterus, fallopian tubes, bladder and rectum. They frequently simulate in growth and gross appearance ovarian

and parovarian cysts. Where the ovary is involved, there is probably always an involvement of the cellular tissue first. Maloney reported a remarkable case of a colony 11 centimetres in diameter growing beneath the serosa of the uterus and communicating with the right fallopian tube, which was greatly distended, thrown into convolutions, and stuffed with vesicles.

Brain.—Hydatid cysts occur in this organ occasionally, entering it from the meninges or from the blood-stream. Most intracranial echinococcus cysts originate in connection with the pia mater, where they develop without much opposition, and therefore frequently lack the fibrous adventitious cyst so commonly present in the more solid organs. Furthermore, these cysts are usually sterile, a fact which is possibly responsible for some erroneous diagnoses. The fact that *Cysticercus cellulosa*, *Cysticercus tenuicollis*, and the larvæ of *Tænia pisiformis*, *Tænia ovis*, and *Multiceps multiceps* have been reported for the brain, makes it still more confusing.

One of the most interesting cases on record is that of Cardenal and Castella,³⁶ who operated on a boy of fourteen one year after a fall on the right parietal region which had caused unconsciousness for two hours. In the interval between accident and operation, the child had epileptiform seizures with coma, which lasted two or three minutes, and which recurred every six or seven days, finally. A right partial hemiplegia also manifested itself. The skull was opened widely in the left rolandic region. The dura beneath the flap was intact. On incising this structure, however, there was an outpouring of echinococcus daughter-cysts. The mother-cyst occupied the space of the anterior third of the left hemisphere, and extended beyond the median line internally. In view of the large area of brain involved, the symptoms were remarkably mild. The child made a good recovery with the exception of a slight flaccid palsy and lack of power to extend the fingers of the right hand. At the seventh month post-operative he had an epileptic seizure, but up to the tenth month, there had been no recurrence.

Morquio, of Argentina, has had seven cases of hydatid of the brain in children. There was no eosinophilia in any of the cases. He states that 5 per cent. of brain tumors, in a series he has observed in children, were echinococcus cysts. They may attain great size

and cause protrusion and thinning of the skull before there is headache, vomiting, or eye symptoms. Sometimes the mind is affected, sometimes there is a unilateral chorea, and sometimes there is sudden death with the cause only apparent at autopsy. Rupture of a cyst in the brain will almost certainly prove fatal, anaphylactic shock, urticaria, cyanosis and collapse preceding death.

Cranium and Spine (Axial Skeleton).—Several cases of echinococcus cysts between the tables of the skull have been reported, and Verco, Rennie and Crago, Mills and MacCormick, and others have reported cysts within the cranium which were extracted after exposure with the trephine. A number of cases have been observed of colonies of cysts within the orbit.

Cysts occur in connection with the spine under the following conditions (Bland-Sutton):

I. Cysts situated entirely within the canal: (a) Between the dura mater and bone, lying in the loose connective tissue; (b) those inside the dura mater.

II. Cysts arising in the vertebræ and extending into the neural canal. Here the primary colony in the vertebra is usually of the multilocular variety.

III. Cysts growing in the tissue adjacent to the spine may involve the vertebræ and extend into the spinal canal.

Schlesenger tabulated 400 tumors of the spinal canal, and of this number, 44 were echinococcus cysts. Of the 44, five were found intradural, and 39 were extradural. His statistics again confirm the fact that echinococcus cysts choose loose cellular tissue, in this case the tissue external to the dura. Theobalds, in the *Lancet* of April 10, 1909, reported an interesting case of involvement of the fourth and fifth lumbar vertebræ.

Other Bones (Appendicular Skeleton).—Comparatively few cases are on record of echinococcus invasion of the bone. Walker and Cummins³⁷ being able to find records of only 88 cases in the literature up to 1917. They quote Alexinsky's statistics which show improvement in 1.9 per cent. of 1950 cases of the disease. This figure corresponds closely with the data of Gangolphe, who found bone involvement in 1.7 per cent. of 3000 cases of the disease in the literature. The multilocular variety of the cyst is practically

always present, and the medullary cavity is occupied by a multitude of vesicles not contained in a mother-cyst. Pressure from within results in atrophy of the shaft of the bone, and fracture is apt to result from trivial violence. Eisendrath was able to collect eighteen cases from the literature, of pathologic fracture due to echinococcus cysts. The colonies may occur in the cancellous tissue at the ends of long bones as well as in the medullary canal. From the cancellous tissue the process occasionally extends to the epiphyseal portion, and from there may enter the joint.

The question as to the part trauma plays as a predisposing cause of bone hydatids is still under investigation. Walker and Cummins assign to it an important rôle. At operation or autopsy, an inflammatory periosteal thickening with atrophy of the bone is found. If the medullary canal has been invaded, its cavity is enlarged at the expense of the shaft. The X-ray is an aid in disclosing a rarefaction of the bone about a colony of cysts. Corlette¹⁰ considers the condition quite analogous to sarcoma of bone as far as its tendencies to metastasize and to infiltrate are concerned. Indeed, clinically it must often be very difficult to differentiate between sarcoma, osteitis fibrosa cystica, and echinococcus cysts of bone, in that the latter are practically always very small, and are sterile. As in other organs and tissues, secondary infection is occasionally superimposed, and the condition changes to one of osteomyelitis.

The femur is more frequently involved than any other bone in the body for the obvious reason that it is the largest. The other bones are involved to a great extent according to relative size. The analogy between fat-embolism and embolization with echinococcus brood-cysts has already been referred to. It is possible that bones are involved by direct hematogenous implantation of embryos which have filtered through the portal and pulmonary circulations. Statistics would seem to bear this out, in that visceral and osseous involvement seldom exist together in the same host. On the other hand, where visceral and osseous involvement do co-exist, it is very difficult to say which was primary. Lack of complete autopsies in proven cases of visceral involvement is another possible source of error, in that examination of the bones is seldom a part of such post-mortem examinations. It is safe to say that large numbers

of instances of bone hydatids go unrecognized because of lack of symptoms and signs pointing to bone involvement.

Muscles, Subcutaneous Tissues and Cellular Tissues.—Colonies of echinococcus cysts may arise in the subcutaneous tissue in any part of the body. In the neck the colonies seem to prefer the subfascial spaces, where they are rather difficult to deal with surgically. Haderern (quoted by Andrews) reported a deeply situated cyst which was attached to the internal carotid artery. This vessel had to be ligated in order to completely remove the cyst. The patient recovered. Andrews was able to collect twenty-nine cases of involvement of the tissues of the neck, in the literature up to 1907. Of this number, the majority were instances of infestation of the thyroid gland, while the next most frequent site was beneath the sternomastoid muscle, and extending deeply to the carotid sheath or beyond. In this latter position hydatids are frequently mistaken for branchial cysts, while in the former location, they are apt to be confused with cystic goitre. Because of the firmness of the fascia of the neck, cysts tend to become loculated as they thrust themselves into the free spaces.

In the abdominal and thoracic walls, the parasite usually chooses the muscles, and next in frequency the peritoneal and subserous tissues of the abdomen and chest, respectively, are involved. In the abdominal wall, the cysts are usually reported in the neighborhood of the umbilicus, although Madelung found them mostly in the lumbar region. In the vast majority of cases, intra-abdominal cysts are also present, and no doubt these are the primary foci in many cases. The mode of probable communication is between the portal and systemic circulations.

Statistics show that the muscles are invaded in about 1.9 per cent. of cases. The embryo or brood-capsule is brought to the muscle by the blood-stream, and once deposited, it undergoes the usual transformation. The resulting cyst pushes the muscle fibres apart in its growth, until it attains its full development, usually about five centimetres. The perimysium forms the outer fibrous or adventitious capsule, and because of the chronic irritation of the foreign body, there is usually more or less inflammatory reaction on the part of the adjacent tissues. If secondary infection takes place,

abscess results, while if in the course of time, the cyst contents die, caseation results or calcium salts are deposited in the mass. Munro recorded a case of echinococcus cyst in the retroperitoneal tissues of the flank which had caused pressure atrophy of the kidneys. At operation, cyst and kidney were both removed.

When infections are present a leucocytosis with eosinophilia may be found, but in chronic cases no general systemic reaction is manifested. The cysts may or may not be sterile. They are occasionally mistaken for *Cysticercus cellulosæ*.

Peritoneal Cavity.—Involvement of the peritoneal cavity is usually secondary to cysts of the contained organs such as the liver and spleen. These cysts may have ruptured spontaneously or been ruptured at operation and have sown the brood-capsules and daughter-cysts upon the serosa, or by exogenous budding from the mother-cyst, propagation of colonics on the peritoneum may have taken place. The appearance of the serosa resembles a tuberculous infection grossly, and is also to be differentiated from infection by the *cysticercus tenuicollis*.

Fairley³⁸ recently analyzed twenty-five cases of peritoneal echinococcosis and found that 88.2 per cent. of the cases had been operated on previously for intra-abdominal hydatid. In seventeen of the twenty-five there were multiple cysts. In five of the cases, calcification or other degenerative change had taken place. He holds the belief, in common with several other observers, that single cysts argue for a primary localization of an embryo after traversing the wall of the gut, or arriving *via* the blood-stream from some distant focus.

With leakage of these cysts there is the usual anaphylactic reaction. With secondary infection there develop the localizing signs of abscess, and the typical systemic reactions. Pelvic cysts produce pressure symptoms earlier than do those situated higher up.

Prostate Gland.—Young, of Baltimore, states that echinococcus cysts of this organ have been described by Nicaise, Lodwell, Winterberg, Butreuil, Tillaux and Millet, and others. It is probable that the great majority of cysts which involve the gland arise in the pelvic cellular tissue primarily. Thus, Bird³⁹ reports three cases of pelvic hydatids, in all of which the prostate became secondarily involved, and daughter-cysts and debris were passed *per urethram*.

SYMPTOMS AND PHYSICAL SIGNS

Occurring as they do in a multitude of locations, the cysts are bound to produce a multitude of different symptoms, and few symptoms, if any, which are pathognomonic of the disease itself. The size and situation of cysts with reference to vital structures has a great deal to do with the chain of symptoms presented.

To begin with the head, if the colony is extradural, or between the tables of the skull, no symptoms are present as a rule unless on increase in size, there is pressure on the brain or irritation of the scalp over the prominence. Within the brain, pressure on various centres will produce symptoms pointing to the area involved. If in the motor area, Jacksonian epilepsy is quite common as in the case already referred to of Castella and Cardenal,³⁶ in which there was a cyst of the anterior third of the left hemisphere. There was a partial right hemiplegia in addition to the epilepsy. Headache is the commonest symptom. Objectively, "egg-shell crackle" of a thinned cranium may lead to a diagnosis if other signs agree, and the biologic tests are positive.

In the neck, the chief symptoms are those of discomfort due to the swelling, and if close to the trachea, there is apt to be dyspnoea, while pressure on the sympathetic may produce pupillary changes; in short the symptoms are very variable, and depend on the pressure exerted on certain structures by the growing cyst. The cysts are said to be hard, and do not fluctuate as a rule. The "hydatid thrill" is demonstrable in perhaps half the cases. Pain is not present as a rule unless secondary infection takes place, when there is added to the picture the phenomena of sepsis. A severe urticaria follows dribbling of the fluid into the subcutaneous tissues after exploratory puncture.

In the chest, symptoms and signs are not usually manifested unless the heart, lungs, or great vessels are involved. When there is an involvement of the heart itself, it may readily be seen at what mechanical disadvantage the heart has to work. Pressure on the neuromuscular conduction fibres would have the effect of interfering with impulses to ventricular contraction. Then too, the accidents of rupture and secondary infection carry with them

a separate and grave set of symptoms depending largely on the position and size of the cyst. Either accident is usually fatal.

Large cysts in the lungs present the symptoms and signs of intrathoracic tumors, and pressure signs sooner or later become rather prominent. Dyspnoea on exertion and the development of an afebrile cough, with occasional hemoptyses might lead to a diagnosis. There is sometimes a profuse foetid expectoration, emaciation and all signs of pulmonary tuberculosis. Where the cyst or cysts rupture into the bronchial tree without fatal effect, a diagnosis is easily made by the finding of the cyst-elements and a large amount of clear fluid. A common sequel of such rupture seems to be secondary infection with resulting lung abscess, and the clinical phenomena of sepsis. Signs of tumor of the lower lobe of the lung, which tumor gradually enlarges and displaces thoracic and abdominal viscera without an accompanying clinical picture of malignancy or sepsis, should put one on his guard for echinococcus disease. (See "Diagnosis," p. 284.) A round shadow is shown by the X-ray.

In the abdomen, a painless swelling connected with the liver or spleen, and which gives a vibratory thrill on percussion, should be suspected of being an echinococcus cyst, especially if the history is suggestive, and there is no evidence of malignancy or syphilis. When these cysts rupture into one of the hollow viscera, and their contents are discharged, the diagnosis is a simple matter as a rule. When secondary infection takes place, the picture changes to that of sepsis.

In the case of the long bones, the symptoms are those of a slow, progressive increase in the size of the bone. In the later stages, pain is complained of, and is worse at night. There may be some œdema of the overlying structures, but no inflammatory reaction is present. "Egg-shell crackle" is eventually elicited, and when this point is reached, spontaneous fracture is a common accident. Secondary infection results in osteomyelitis with the symptoms and signs that accompany that affection. In Walker and Cummins' case,³⁷ the Greek, thirty-one years of age, had complained of paroxysmal pain in the upper third of the tibia for about three years. The pain was worse at night. At times the leg became much swollen over the area of pain. There was no history of syphilis, trauma, or association

with dogs. He was poorly nourished, but presented no evidence of tuberculosis. Blood and urine were negative. X-ray examination showed a cystic condition of the upper third of the tibia. The definite diagnosis was made at operation.

DIAGNOSIS

A complete description of the adult parasite is given in a previous paragraph. As the principal pathology, and the phenomena which affect man are limited to the larval cycle, the cyst stage, it is this aspect only of the disease which will here be considered. The diagnosis is made by a process of exclusion in the majority of cases, if indeed a diagnosis is made at all before operation or autopsy. In countries where the disease is rare, the diagnosis is seldom made until the cysts are discovered in the course of operation or autopsy. And yet there are very definite reasons why a diagnosis should, if possible, be made before any surgical treatment is instituted. Volkmann (1887) early called attention to the dangers from puncture of these cysts. The immediate danger is from anaphylactic shock due to spilling of cyst-fluid, and the remote danger is from the implantation of elements which may develop into new cysts.

In countries where the disease is prevalent, very commonly the diagnosis is arrived at through the medium of the complement-fixation test, the precipitin reaction, or one of the other biologic tests. The complement-fixation test (first used in the diagnosis of echinococcus disease by Apphatie and Lorentz, in 1908, in Argentina¹⁶) is applied in the same way as is the Wassermann reaction. Ehrlich showed that hydatid disease produces in the host antibodies of the third order. In this instance, the preserved fluid from a human or animal hydatid cyst is used as antigen.

The materials required for the test are: (a) Antigen, fluid from a known echinococcus cyst; (b) complement, normal guinea-pig serum; (c) serum of the patient suspected of having the disease, the serum having first been inactivated by heating to 54° C. for 30 minutes (to destroy complement); (d) sheep amboceptors; (e) a 2.5 per cent. mixture of defibrinated sheep erythrocytes, free from serum and suspended in normal saline.

The *precipitin reaction* (Fleig and Lisbonne, 1907) is conducted

as follows: Equal parts of the patient's serum and hydatid fluid (obtained under aseptic precautions from another patient or one of the animal hosts) are mixed. A distinct flocculent precipitate in 5 to 30 minutes indicates a positive reaction. If after one hour the mixture is clear or only slightly turbid, the test may be regarded as negative. Simultaneous controls should be run, using serum of normal person and that of a patient known to have the disease.

Casoni's method of *intradermal injection* is by far the simplest test, and according to Pontano⁴⁰ is positive in 84 per cent. of cases. By this method 0.2 to 0.3 c.c. of fluid from a hydatid cyst of an animal is injected into the skin of the patient. If positive, a local reddening and an urticarial wheal develop. In his experiments, Pontano found that subcutaneous injection produced a reaction in 66 per cent. of cases, the complement-fixation test was positive in only 50 per cent., and an eosinophilia was present in only 40 per cent. of cases. He is enthusiastic over the *intradermal test* because of its high percentage of positive results, and because the complement-fixation test is negative when suppuration is present in the cyst, while the *Casoni test* is often positive even with this complication. He found suppuration in the cyst to be the principal cause for the negative reactions sometimes obtained. He states that fluid from a hydatid cyst is an antigen capable of sensitizing normal persons. On the other hand, such investigators as Zapelloni,⁴¹ in a series of 500 collected cases, found the complement-fixation test positive in 93 per cent., whereas Luridiana⁴² investigated both the complement-fixation and the intradermal tests in his series of cases, and found one was sometimes positive when the other was negative. He therefore advises using both tests on each suspect. Everything considered, it would seem that Luridiana's advice is worth following where possible.

There are three other tests deserving of mention. These are: (1) The *miostagmin reaction of Ascoli* (1910) which consists in mixing nine parts of the patient's serum with one part of antigen, and counting the number of drops, in a unit of time, which flow from a Traube stalagmometer; (2) the *Abderhalden test* which consists of the dialization and extraction of an emulsion of equal parts of antigen and the patient's serum; (3) the *cutaneous test*, done with

sterile hydatid fluid much as one would do the Von Pirquet test, the principle being to show a specific allergic reaction as in similar tests for protein sensitization.

Blood examination in an uncomplicated case of hydatid disease may reveal a small percentage of eosinophiles. After puncture of a cyst, or rupture, there is apt to be a definite eosinophilia. However, many authorities place no confidence in eosinophilia as determining the presence of the disease.

The X-ray is regarded by some as being very valuable in the diagnosis of the condition in the lungs. This is probably true when confirmed by history, symptoms, physical signs and biologic tests. The X-ray shadow is round with well-defined borders, in contrast with cancer, abscess (?) and tuberculosis, in which conditions the shape is usually irregular, and the borders ill defined. The fluoroscope will differentiate the pulsations of an aneurism from the non-pulsating cyst. The X-ray in other parts of the body is of much less value in diagnosis. The cyst-mass shows as a dark shadow as a rule. In the case of the liver, if the cysts be of the upper portion organ, the diaphragm is elevated, in contradistinction to a hydrothorax, where the dome of the diaphragm is depressed.

Exploratory puncture is to be condemned except in the most superficial cysts, *e.g.*, those under the skin, or in easily accessible muscles, where excision or marsupialization can be carried out if a cyst is proven to exist. Here, the finding of a clear, neutral, non-albuminous fluid of 1.005 to 1.015 specific gravity, and containing hooklets or scolices, is fair presumptive evidence of the disease, cysticercus cellulossæ having been carefully ruled out. The fluid is said not to be toxic to laboratory animals, whereas the fluid from cysticercus tenuicollis, cysticercus cellulossæ and other cestode larvæ is more or less toxic, producing urticaria and other allergic symptoms on injection. The specific toxin is said to be a leucomain or a body close to histamine. On the other hand, if any of the fluid is spilled into the tissues during withdrawal of the needle, or during operation on a cyst, an urticaria is sure to result, in the human subject, and if much fluid is spilled, violent intoxication, and even death, may result from anaphylactic shock.

The life cycle of the parasite has been discussed, and under that

heading the chief characteristics of a cyst were mentioned. However, owing to the necessity for making a definite diagnosis before operative drainage or removal is undertaken, the chief points which distinguish the echinococcus cyst will be delineated: In the first place a cyst or cysts sufficiently large to produce symptoms or to be palpable through the abdominal wall, or to throw a characteristic shadow upon an X-ray plate, will usually be found at operation to be not less than four to six centimetres in diameter. Echinococcus cysts have been reported as large as a child's head. In the solid organs of the abdomen, they are usually found presenting one-fourth or more of their surface into the peritoneal cavity. The remainder of the cyst is embedded and, if near the edge of the organ, may be palpable almost in its entirety. Cysts in the omentum may be brought out of the wound and examined carefully.

Beneath the smooth peritoneal covering will be seen the fibres of the laminated adventitious coat which is supplied by the invaded organ. If this is incised or bluntly separated over the convexity of the cyst, the glistening, pearly white, outer coat of the cyst-parenchyma is exposed. If now, with proper precautions this layer is excised through its entire thickness, fluid and small cysts and cyst-membrane will exude from the opening. If the fluid is examined under the microscope, it will be found in a fair proportion of cases to contain scolices and hooklets. This is the most characteristic feature of the cyst produced by the embryo of *Tænia echinococcus*, that it produces thousands or even millions of scolices which spring from a single onchosphere. The larvæ of other tænia produce one or at most only a few scolices.

As already stated the cyst-wall is chemically allied to chitin, or is between it and the proteins. When boiled with acid, this yields 50 per cent. of a reducing sugar-like body. Glycogen is usually capable of being demonstrated but is limited to the germinal membrane (Wells).

As has been said, the contained fluid is of a specific gravity between 1.005 and 1.015. It contains about 1.5 per cent. to 2 per cent. of solids, 0.8 per cent. of which is sodium chloride and 0.25 per cent. sugar. The molecular concentration of the fluid is about the same as the patient's blood (Schilling; Wells). Proteins are

present only in traces except where inflammation exists. Cholesterol is often abundant, while inosite, creatin and succinic acid are frequently present in traces.

The following cystic conditions are to be considered before diagnosing echinococcus disease in the absence of scolices and hooklets: Retention, distention and exudation cysts; proliferation cysts; congenital cystic disease (as of the liver, kidneys, and rarely of the pancreas); hemorrhagic cysts; pseudocysts, as of the pancreas, not arising in the substance of the gland itself; ovarian and parovarian cysts; and last, but not least, in importance, *Cysticercus tenuicollis* (the larval stage of *Taenia hydatigena*), which has frequently been reported for man. In the abdomen it (*Cysticercus tenuicollis*) is found embedded in the liver, or, more often, hanging from its surface or attached to the mesenteries or omenta. It resembles a sac full of clear fluid, with a white object (the head and neck) projecting into it from one end. It is ovoglobular, about 2.5 centimetres in diameter, and perhaps five to seven centimetres in length. As in the case of the echinococcus cyst, the host throws about the cyst an adventitious coat as protection. If this coat is broken through, and the parasite shelled out, it is found to be a thin-walled bladder, from one end of which the single scolex may be expressed.

In bone, the chief conditions to be excluded are sarcoma, osteomyelitis, and osteitis fibrosa cystica. In the chest, neoplasm, aneurism, tuberculosis, broncho-pulmonary spirochetosis, and pneumonia are to be excluded. Faggiola, in 1919, reported a case of "primary echinococcus of the lung" which was diagnosed by the X-ray, and confirmed by puncture and complement fixation. The original diagnosis was broncho-pneumonia with infiltration of the upper and middle lobes of the right lung, plus pleurisy with effusion on the same side. X-ray showed three large cysts, two in the lung, and a third in the posterior pleural sac. The puncture—a procedure which is not recommended—was followed by the usual symptoms of anaphylaxis, and by the appearance in the sputum of a large number of eosinophilia.

Cysts in the subcutaneous tissues are to be differentiated from wens, dermoids and lipomas.

The differential diagnosis in the abdomen involves the following considerations:

(a) A gumma of the liver is firm, painless and rarely fluctuates. There are other evidences of syphilis; (b) a cancer of the liver is to be excluded by the history of the case and the absence of a primary growth, as well as by the biologic tests. Primary carcinoma is rare, and usually requires laparotomy for diagnosis; (c) hydronephrosis and congenital cystic disease of the kidney are to be excluded by history, symptoms, ureteral catheterization, pyelography, etc.; (d) abscess of the liver is ruled out by the local signs of suppuration and the general symptoms of sepsis in this condition; (e) subphrenic abscess is to be excluded. Here as in right-sided empyema, the symptoms of sepsis would preclude the presence of uncomplicated echinococcus disease.

In short, a slow-growing, painless, swelling or fluctuating tumor connected with the liver or presenting in the epigastrium, should be suspected as an echinococcus cyst, and especially in the presence of hydatid fremitus, positive biologic tests, and an eosinophilia.

PROPHYLAXIS

In prevention lies the best remedy for this scourge, and, as has been shown, it is a scourge in some countries. It is already a menace to the health of many communities in North and South America to-day. I cannot do better in this connection than to mention the work of Maurice C. Hall, and to quote from the outline contained in a concise little booklet by him, "Farmers' Bulletin 1150" (United States Department of Agriculture, Bureau of Animal Industry, 1920). What he says regarding sheep holds true, in many particulars, with reference to hogs, other domestic animals, and even man:

"Sheep probably suffer more from parasites than do any other kind of livestock. Most of our loss in sheep, mutton, and wool is from animal parasites, as sheep suffer comparatively little from bacterial diseases. Lambs and young animals are most susceptible to parasites and suffer most from them. It is the sheepman's business to prevent disease. When disease is present it is desirable to call in a competent veterinarian. Pasture rotation, use of forage crops, feeding from racks or bare floors, draining or filling swamps, and restraint of wandering dogs are measures of value in parasite control. Permanent pastures perpetuate parasites! Parasite eggs pass in the manure usually. The disposal of the manure

determines the fate of these eggs. Parasitized animals usually do not have fever; they are unthrifty. This unthriftiness may have a fatal termination. Act promptly to ascertain the trouble when sheep become unthrifty. A post-mortem examination of one of the sick animals may disclose the trouble and save the others."

In still another bulletin, Hall calls attention to the recent abattoir figures which show an alarming increase in the incidence of the disease in domestic animals in some parts of the United States, especially in Virginia, Arkansas, and Oklahoma. Where the disease prevails among domestic animals, man is a potential victim, and it behooves the stockman, the veterinarian and the meat-inspector to be ever on the alert to interrupt the cycle in its incipency. Finding of the disease in a drove of sheep or in a herd of cattle or swine should be equivalent to signing a life-time quarantine for faithful Rover. He it is that harbors the adult worm, millions of them, probably, on the villæ of his duodenum and upper jejunum. The *Tænia echinococcus* and the *Tænia nana* are the smallest of all of the cestodes. Hall is quoted by Johnston and Willis (*loc. cit.*) as saying that "the bare fact that hydatids occur at all in the United States is of itself a cogent argument for the suppression of the dog nuisance as a measure necessary for the public welfare."

Johnston and Willis¹³ trace the small epidemic of the disease among human beings, which they report, to an epidemic among hogs. Indeed they liken the rôle of the hog in Virginia to that of the sheep in Iceland and Australia. It is often difficult to determine the exact mode of infection of man, whether through the ingestion of ova, or through the eating of infested organs of sheep or hog. We do know, however, that the dog is the primary host for the *Tænia echinococcus* in the vast majority of cases, and in Hall's recommendations for the "suppression of the dog nuisance" seems to lie the solution of the problem where the disease is endemic.

In the prevention of echinococcus infection, we are automatically preventing cysticercosis. Thus, *Cysticercus tenuicollis*, which is reported as a comparatively frequent invader of the human body, grows from the eggs of *Tænia hydatigena*, which worm resides in the small bowel of the dogs also. Careful autopsy of animals dying of any obscure infection is one of our best methods of gaining

knowledge which may save from infection other animals and man. I have called attention to the growing tendency to study the relationship of animal infection and infestation to human disease. Every city of any considerable size should foster a society of comparative pathology, so that outbreaks of epidemic disease in the lower animals may be discovered early, discussed intelligently by physicians, veterinarians and others trained in the medical sciences, and eradicated. Not only epidemic diseases, but all diseases and anomalies should be aired in open forum in such a society or league, thus assuring better coöperation between the welfare organizations of the community.

In this connection it will be of interest to quote from a resolution adopted in July, 1922, by the Society of Comparative Pathology of Paris, and presented by Doctors Devé, Weinberg and Morel (Paris letter to *Jour. Am. Med. Asso.*, Aug. 4, 1922):

"RESOLVED: That private slaughter-houses be suppressed and be replaced by communal abattoirs.

"That the legislative enactments concerning the seizure of stray dogs and the destruction of animal carcasses be strictly enforced.

"That dogs should not be permitted to enter the flaying rooms at all, and the abattoirs only to a limited extent, as controlled by definite regulations.

"That the declaration of all animals discovered in the abattoirs to be infested with echinococci shall be obligatory."

It has been further suggested, that, in the regions where animals are discovered harboring the disease, the public, the farmers and the butchers be advised by articles in the daily papers, by leaflets, and by lectures, of the dangers of the disease and means to avoid it.

TREATMENT

It would seem to be desirable to mention first the treatment of the intestinal taniasis in the primary host. Authorities seem to agree that dogs and cats should be kept free of tape-worms by giving them vermifuges every three or four months. In this way, too, by saving and examining the stool, one is able to determine which worm, if any, is present in the animal's alimentary tract. Among the *Tenia* to be expected are *T. echinococcus*, *T. hydatigena*, *Multiceps multiceps*, *T. nana*, and *T. ovis*. The animal is fasted for eighteen to twenty-four hours, and is then given one to four c.c. of the oleoresin of male-fern in capsules. This dose is immediately

followed by an ounce of castor oil. Areca nut, if freshly ground, is preferred by some, while others administer kamala, two to six grams. In the case of the two latter remedies, if no bowel movement occurs in four or five hours, a purgative should be given. After examination, the feces should be burned. Dogs persistently harboring the *tænia* should be exterminated.

The only proper treatment of echinococcus disease in the secondary host is surgery. The method of procedure will necessarily vary with the situation of the cyst itself. Aspiratory puncture is applicable to only a very few cases, and is mentioned for the purpose of condemning it. The dangers attending the spilling of cyst-fluid during operation or puncture have been enumerated, and any plan of operation, to bring permanent cure must have as a fundamental principle, the safeguarding of exposed tissues. There is no excuse for such meddlesome methods as electrolysis. In general terms, the ideal of surgery is to remove the cyst *in toto* where possible, and if not possible, to remove as much as is practicable, and then either marsupialize or thoroughly drain. Aspiration remains as a last choice in those cases where none of the above procedures is applicable. In the treatment of echinococcus cysts of the liver, the technic of the Mayos will be found to embody the principles just mentioned. The operation of incision and enucleation of the cyst was first described in 1883 by Thornton. In France the same operation bears the name of Delbet.

The steps of the operation are as follows:

(1) The abdomen is opened by a vertical incision over the most prominent portion of the tumor, the incision extending a safe distance above and below the mass.

(2) The cut edges of the parietes and the general peritoneal cavity are well protected by gauze packing to prevent implantation of cysts or scolices.

(3) An aspiration trocar with rubber tubing connected is introduced into the cyst at a point where it comes nearest to the surface of the liver. As much of the fluid as possible is evacuated.

(4) The trocar is withdrawn and the incision enlarged, extending as far into the liver as is compatible with safety.

(5) The edges of the wound in the liver are covered with gauze, and retracted. Bleeding is in this manner controlled.

(6) The cyst is now opened and the contents are evacuated.

(7) The mother-cyst is next removed.

(8) Where possible, the cavity in the liver is closed with fine catgut on a curved needle—the procedure known as *capitonnage*. Where such closure is not possible, a few strips of rubber tissue are inserted and brought out through a separate stab-wound below the right costal margin.

The operation of incision and drainage is the one usually performed. The steps are much the same as in the operation just described, except that the incisions need not be so large, either in the parietes or in the liver. After the cyst has been evacuated, its edges are carefully sutured to the parietal peritoneum, the process being known as marsupialization (Lindemann's operation). If the cyst is small, a rubber drainage tube is inserted. If large, the cavity is packed with gauze plus a rubber drainage tube. An external dressing of dry sterile gauze is applied. The cavity is repacked at intervals until it contracts and is obliterated, the cyst-membrane usually being cast off in two or three weeks. In large cysts, healing sometimes takes six months, and then the defect must be closed by a plastic operation. In smaller cysts, the operation of "capitonnage" or obliteration of the cyst-cavity is often practised—using "U" sutures of catgut to approximate the walls.

In the case of suppuration of an echinococcus cyst of the liver, either of the operations described may be performed, but ample drainage should be provided for.

Cysts which protrude upward against the diaphragm from the right lobe may require the resection of a portion of two or three ribs for proper exposure. If the pleura cannot be pushed up out of the way, both layers may be sutured to the diaphragm before opening the cyst; or the so-called two-stage operation may be performed. In the latter case, gauze is packed down against the cyst and left there for forty-eight hours or longer to excite the formation of adhesions. At the end of this time the cyst is evacuated in the usual way—due care being taken to protect the wound edges.

The technic for operation upon cysts of the lungs does not vary

in great detail from that of cysts of the liver. The general rules for operating for empyema should be observed. Corlette has proposed, and employs, a technic for operating upon large hydatid cysts of the lungs, *i.e.*, "evacuation of the cyst followed by immediate closure of the chest-wall without drainage." He also advises the "radical extirpation" of old calcified cysts in other locations, with the capsule, providing the operator is an experienced man. Delagenière has advised the gradual production of a pneumothorax by opening the pleura slowly. The cyst is exposed by incising the lung tissue or overlying pleura, is opened after protecting the wound with gauze, and is then evacuated. If complete removal of the parent cyst is not feasible, marsupialization and packing of the cavity meets with very good success. Brewer injects the cavity daily with a solution of silver nitrate, 1:8000, gradually increasing the strength to 1:1000. At a later period he uses the Bier cups to hasten healing and to collapse the cavity. Devé sterilizes the cyst interior with formaldehyde.

French literature is full of reports of operations upon echinococcus cysts of the lungs. Guimbellot, in 1910 ("Thèse de Paris") collected 225 cases which were treated surgically, with 87 per cent. cures. When the suppurating cysts are excluded, the cures amount to 91.8 per cent. Tuffier reported thirty-five operations with but one death. Albertin and Barjon reported a case of two cysts of the right lung—one of the upper lobe near the apex, and one at the base, which were removed one at a time, six months apart, with recovery of the patient. For these operations, local anæsthetic and the patient in the "jockey position"—the so-called Lamas-Mondino technic, with patient astraddle of the operating table, and shoulders bent forward—are said to be a great advantage. Rib resection over the previously localized cyst is performed, the parietal pleura is opened and a gauze tampon is packed down against the cyst. The second stage, evacuation, is performed in twelve to thirteen days (Prat⁴³). Drainage is usually completed at the end of two or three months.

Hydatid cysts of bone usually require incision, evacuation and drainage. Where there is considerable bone destruction, a fracture, or a large joint is invaded, amputation is often the operation of choice. Each case presents its particular problems, and no specific

rules can be laid down which will apply to all cases. However, the general rules as regards the protection of the fresh wound edges, and thorough removal of all cyst-membrane and fluid, should be borne in mind. It has been said that all the elements that characterize sarcoma are present in bone hydatids except the morphology. The surgeon should therefore act accordingly.

Cysts of muscles may be excised, incised and drained, or evacuated through a canula and injected with antiseptic solutions. Excision is to be preferred. Where this is not possible, incision is done after protecting the wound edges. The gelatinous walls of the mother-cyst are curetted with gauze, and drainage is provided for.

Echinococci of the brain, spinal cord and vertebræ have been successfully operated upon (Cardenal and Castella; Verco; Rennie and Crago; Mills and MacCormick; Tytler and Williamson). In the superficial cysts, good results are the rule, but in the central ones, the reverse is true. General rules for localization and trephining apply here as in other tumors of the central nervous system.

Hydatid cysts of the kidney are treated by nephrectomy, or by nephrotomy with resection of the cyst where possible, and under the precautions above outlined. Kretschmer³⁴ reviews all phases of the surgery of echinococcus disease of the kidney, and outlines four methods of dealing with it in this location: (*a*) Delbet's operation, usually impracticable; (*b*) nephrotomy, justifiable where the cyst is very large, or the patient too weak to withstand (*c*) resection, or (*d*) nephrectomy. Of the eighteen American cases reviewed by Kretschmer, nine were nephrectomized. There was one death, due evidently to spilling of fluid and debris into the wound when the cyst ruptured. If resection of the cyst cannot be done safely, it is far better to do a nephrectomy.

In the case of the spleen, there are usually so many adhesions that the only safe procedure is splenostomy, the lips of the incision in the spleen or adventitious sac being sutured to the skin. The defect in the abdominal wall is repaired later. According to Fowler⁴⁴ there were only 100 cases of cysts of the spleen recorded up to 1890, and the mortality for the twenty-three cases splenectomized up to 1908 is given as 17 per cent. Before a cure of the

disease is pronounced, the liver should be carefully gone over for evidences of cysts of that organ.

Cysts of the pancreas must be dealt with according to location. A good plan, followed by the few men who have operated upon cysts in this location, is to marsupialize the pericystic pouch and apply a mild antiseptic such as Dakin's solution to the interior of the pouch. Albo³² mentioned the use of hypodermic injections of one c.c. of adrenalin chloride solution to preclude the development of shock and anaphylaxis, both during and after the operation.

Hydatid cysts low down in the female pelvis should be attacked by the vaginal route if possible, thus doing away with the chance of soiling the peritoneal cavity.

In general it may be said that echinococcus cysts and colonies, if not too wide-spread, may be eradicated by surgery, but the disease is very persistent and requires patience on the part of the surgeon and the victim of the disease.

SUMMARY AND CONCLUSIONS

An effort has been made to assemble all of the important facts regarding echinococcus disease into one monograph.

It is obviously a disease which is on the increase in the United States, and might therefore be a worthy subject for more thorough investigation.

There is still considerable to be learned regarding the disease, as is shown by the fact that able pathologists and helminthologists disagree on the subject of the number of species of the parasite, and the mode of transmission of the disease to man and other secondary hosts.

With a means of specific diagnosis at our disposal, it should not be difficult to go through an entire community or herd and pick out carriers of the disease.

The dog and, to a lesser extent, the cat are deserving of the gravest suspicion whenever the disease breaks out in the flock or herd, or becomes epidemic in man. In the segregation of dogs and cats lies the solution of the problem as regards prevention.

With Iceland, Argentina, and Australia as horrible examples before us, we should be stimulated to an active effort to stamp out the disease in the United States, and prevent its further entrance.

In view of the fact that the chief characteristics of the disease are the same, no matter what the host, I have seen fit to illustrate the pathology in a number of the organs by means of photographs of specimens from my own case, an ape, *Cynocephalus porcaricus*.

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